Visual acuity – more than meets the eye?

1 CET POINT

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This article considers the limitations of the commonly used methods for measuring visual acuity, and explores the developments in the field to address these issues.

Optometrists

Dispensing opticians

Introduction

Visual acuity assessment is the most commonly employed test within any ophthalmic examination. It is important for: detecting and monitoring refractive deficiencies and other visual system abnormalities; for occupational and medico-legal assessments including defining driving standards; classifying and assessing eligibility for visual impairment registration; and as inclusion and outcome measures in research. Visual acuity assessment was even employed over 1000 years ago when the desert Bedouins used the ability to discriminate double stars as an evaluation of vision. Since then, numerous different visual acuity tests have become available ***(see Figure 1)***, with the advent of the Snellen chart in the 19th century being an important landmark in the standardisation of measurement procedures.

The limitations of the Snellen chart are widely acknowledged,[1] yet remarkably, it remains in common use within many clinical environments including hospital departments, GP surgeries and optometry practice, owing to its familiarity, ease of use and quick testing times.

LogMAR testing

Over the years, the importance of precise and repeatable visual acuity measurements has become more and more recognised. Yet it is only in recent times, with the introduction of anti-vascular endothelial growth factor (anti-VEGF) therapies for treating neovascular age-related macular degeneration (AMD), where changes in acuity must be reliably demonstrated, that Logarithm of

Figure 1

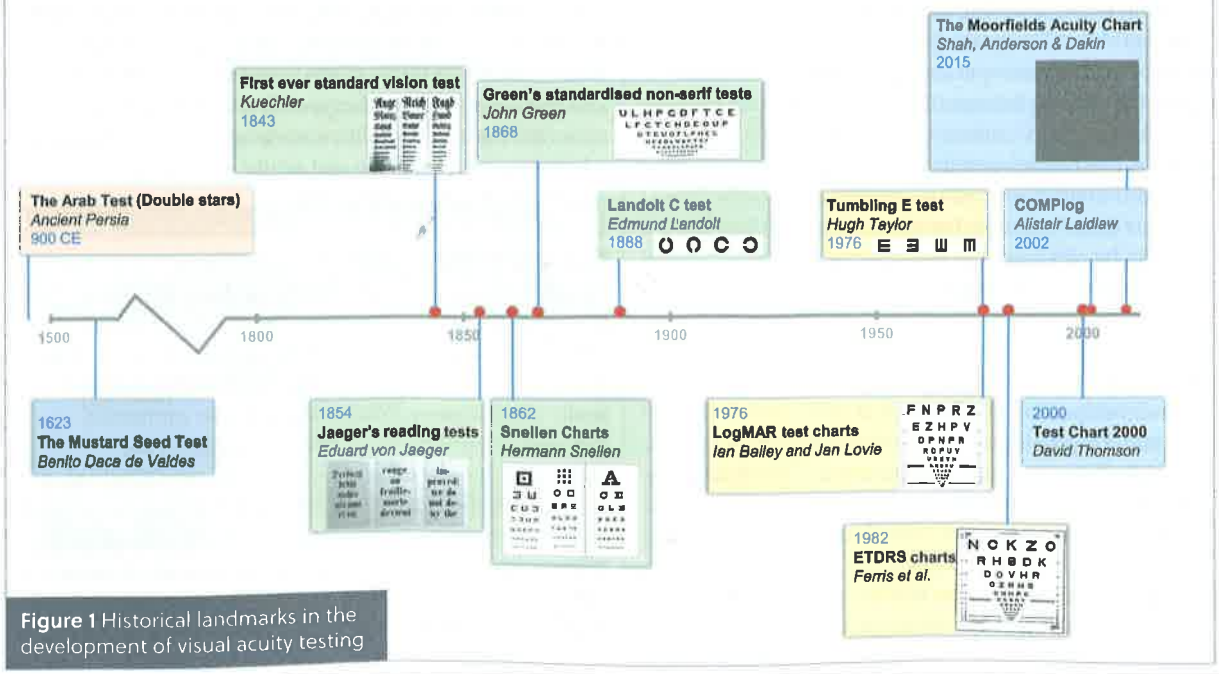

Figure 1 Historical landmarks in the development of visual acuity testing

Figure 2

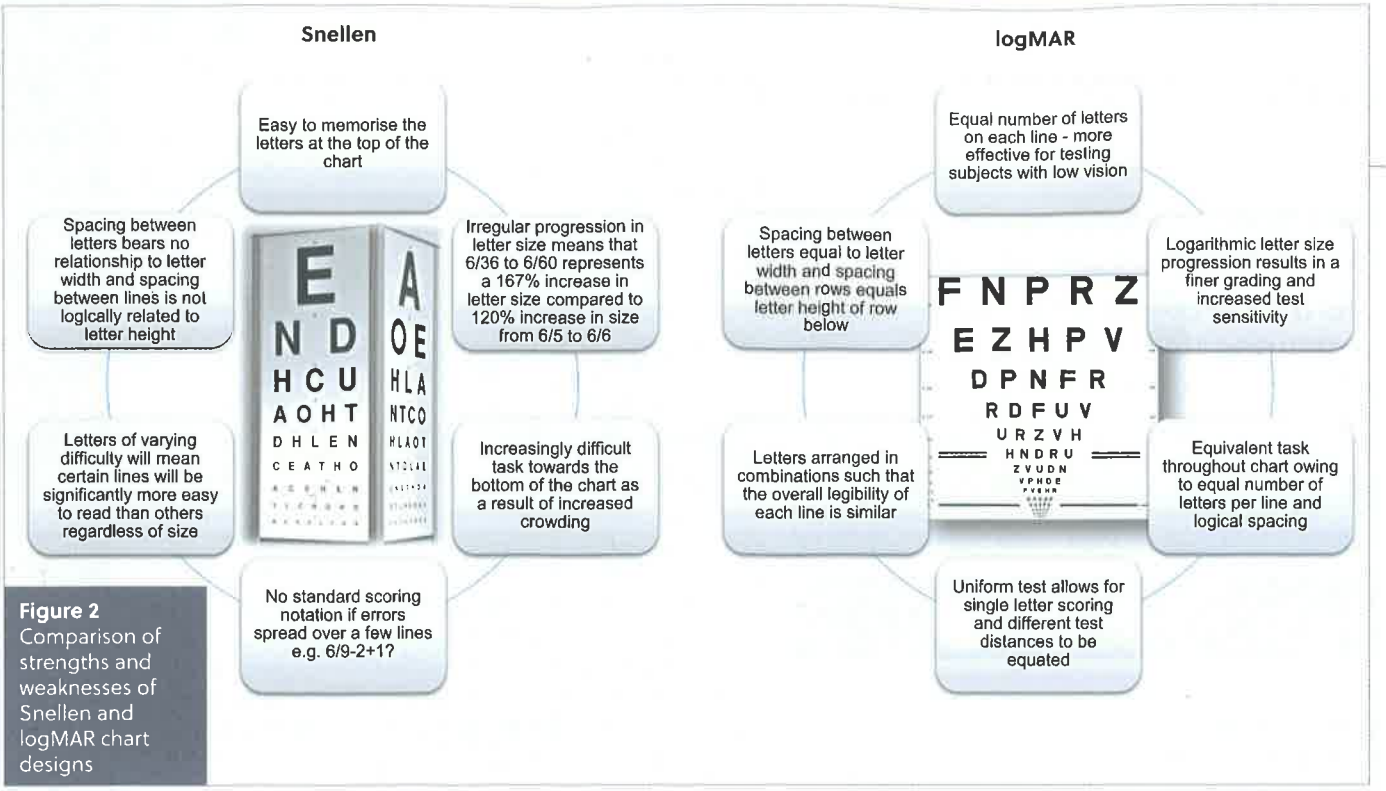

Figure 2 Comparison of strengths and weaknesses of Snellen and logMAR chart designs

the Minimum Angle of Resolution (logMAR) charts have finally begun to appear as the standard chart for testing in clinical environments. The Bailey-Lovie logMAR chart was designed by Ian Bailey and Jan Lovie of the Kooyong Low Vision Service in Melbourne specifically for their study investigating vision loss in AMD.[2] Bailey-Lovie charts incorporate the British Standard Letter set (D E F H N P R U V Z) designed on a 4 x 5 grid. Each row contains five letters, reducing the concerns about letter memorisation that occurred with low vision patients, or non-uniform crowding when assessing amblyopic patients using the Snellen chart. The spacing between letters is uniform with between-letter spacing equivalent to one letter width and the spacing between lines equal to the letter height of the lower row. A uniform logarithmic progression in line size is used which results in a chart with standardised contour interaction and an equal test task throughout the chart ***(see Figure 2)***. For this reason, logMAR chart testing can be conducted at non-standard test distances with scores adjusted appropriately.

ETDRS charts

The Early Treatment for Diabetic Retinopathy Study (ETDRS) charts,[3] were developed by Rick Ferris *et al* of the National Eye Institute. Employing the chart layout of the Bailey-Lovie logMAR charts, they also incorporated the recommendations of the Committee on Vision of the National Academy of Sciences-National Research Council (NAS-NRC) Working Group 39 by using a 4m test distance and incorporating the Sloan letter set (C D H K N O R S V Z) based on a 5 x 5 letter grid design. The only deviation from the recommendations was the use of five rather than ten letters per line with combinations arranged such that each line is of the same average intermediate difficulty. These became known as the ETDRS charts and a scoring protocol was developed in which credit is given to each and every letter read correctly (termed 'by-letter scoring'). In recent times, recording acuity scores in logMAR has shifted to reporting in terms of the number of ETDRS letters whereby 35 ETDRS letters denotes 1.00 logMAR and 85 ETDRS letters represents 0.00 logMAR; this is also useful to patients who are much better able to understand measurements in terms of the 'number of letters gain/loss' they may have undergone. It also makes things easier for the clinician who is no longer required to guess which line represents the real acuity when a patient makes errors across several lines.

Computerised tests

In recent years, electronic testing has been a natural progression allowing for improved control over test contrast and illumination, and integration into electronic records. Test Chart 2000 was the first Windows-based acuity chart system. While there are now numerous different computerised systems available on the market, each presenting a variety of charts, COMPlog, a computerised acuity measurement device was developed to also control the test procedure. COMPlog employs computerised algorithms with automated termination criteria and score calculation ***(see Figure 3)*** and has been extensively validated against the gold standard ETDRS

chart,[4-8] with the aim being to produce a tool which measures acuity in a more standardised way rather than leaving the decision-making to the tester.

Test limitations

While visual acuity measurements are an essential component of every patient examination, there remain two fundamental limitations with the current gold standard tests of acuity, which will be described. These have important implications when deciding on a change-criterion; a change in visual acuity that can be deemed to be clinically important.

Validity

The validity of a clinical test is described in terms of its sensitivity and specificity. The sensitivity of a visual acuity test relates to the ability of the test to correctly detect and identify a reduction in visual function when it has truly occurred. Specificity relates to the ability of the visual acuity test to correctly identify those individuals in which no change in visual function has occurred. A highly specific test will also have a low false positive rate (incorrectly identifying a change when one has not occurred). A test's sensitivity and specificity is directly correlated to the test variability, which is discussed later.

In a study on normal subjects, conducted under strict testing conditions, Rosser *et al*,[9] demonstrated that a line of acuity loss on the ETDRS chart, induced by altering the test distance, went undetected in 62% of individuals. Under normal clinical testing conditions, this is likely to be even worse. This is highly concerning since one of the considered criteria for retreatment with anti-VEGF therapies in neovascular AMD, where these charts are usually employed, is a loss of acuity, often

Figure 3

Figure 3 Appearance of the COMPlog user interface

Figure 4

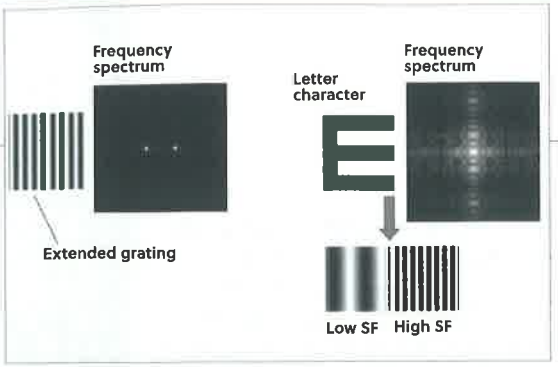

Figure 4 Spatial frequency amplitude spectra of a sinusoidal grating and Sloan letter

specified as being one line. Much consideration has been given over the years to the selection and style of letters incorporated in visual acuity test charts. The basic building block of visual stimuli is the sinusoidal grating but, unlike sinusoids, which possess a single spatial frequency and orientation, letters contain a large number of different spatial frequencies at different orientations and phases ***(see Figure 4)***. These rich spatial frequency spectra make conventional letters excellent targets for detecting optical defocus during refraction as a result of the induced phase reversals that occur, but are these logMAR charts sufficiently sensitive for detecting neural losses of vision such as in AMD? Several studies have shown a reduction of only two or fewer letters in patients with early AMD,[10,11] and visual acuity can often remain normal until the fovea is observably affected even in cases of advanced AMD.[12]

Variability

Every clinician is familiar with the dilemma and frustrations faced when a patient's visual acuity appears reduced compared to a previous visit but no change in clinical status is apparent. This difference in acuity can be due to test-retest variability (TRV), which is a measure of the noise inherent in a threshold measurement in an individual, even when no clinical change has occurred. TRV can be influenced by a number of factors and has been shown to increase in the presence of optical defocus,[13] and ocular pathology.[14] Acuity test design and scoring techniques also impact TRV values. With Snellen charts, a line assignment scoring technique is usually adopted whereby the visual acuity is taken as the smallest line on which the majority of the letters are correctly identified. With this technique, patients are given credit for lines and not letters. Line scoring with the Snellen chart has been shown to result in large values of TRV, and combined with its other design flaws, is recognised as being a poorly

repeatable test.[1] With the advent of logMAR visual acuity charts with rows containing equal numbers of letters and systematic changes in line size and spacing, TRV scores have significantly improved, using both the line assignment scoring technique, and even further with the single letter scoring protocol,[3] which has become gold standard with these charts. Nevertheless, TRV values of up to two logMAR lines have still been reported even with the single letter-scoring algorithm employed with logMAR charts. Furthermore, there are no widely agreed testing and termination criteria.

Letter legibility differences

Conventional black-on-white letters have two distinct visual thresholds: the detection threshold, where contrast is just visible; and the recognition threshold where the letter can actually be identified. Initially, channels tuned to low spatial frequencies detect the letter and, as the letter is increased in size, channels tuned to higher spatial frequencies are successively recruited to supply more detail until the recognition threshold is reached, at which point the letter can be correctly identified. Conventional letters particularly vary in their low spatial frequency content (the energy near the centre of the spectrum in ***Figure 4***) so that two letters that are very different in their low spatial frequency information such as the letters 'A' and 'U', can remain distinguishable from one another for far longer than two letters that are more similar in their low spatial frequency information but differ in their high-frequency information, for example, the letters 'O' and 'Q'. Such individual letter legibility is also dependent on the number and identity of other letter choices available.

Opinions have been divided as to which letters should be employed in a chart: using 'easy to identify' letters; or using 'difficult to identify' letters. The impact this has is a change in the acuity threshold attained. The Sloan letters employed on the ETDRS chart are actually arranged in combinations such that each line incorporates easy and difficult letters so that the overall legibility of each line is similar. However, one source of variability in acuity measurements arises as a result of this variation in discrimination thresholds between letters. Clinicians will be familiar with scenarios in which a patient is able to identify certain letters over a number of lines, while missing other letters over the same lines. If the difference in legibility within a line is greater than the legibility differences between lines, the test may display higher variability and this is an area where there is potentially room for improvement in test chart design.

Figure 5

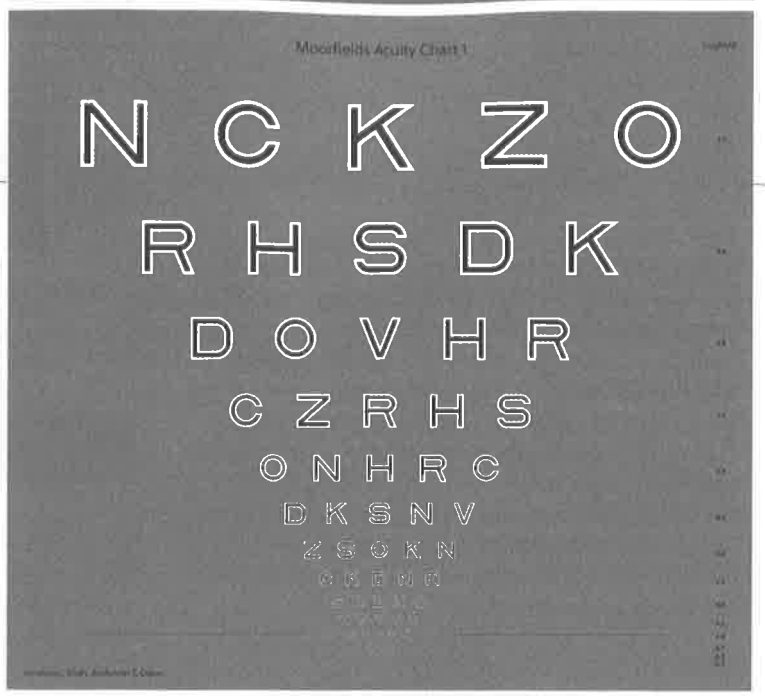

Figure 5 Appearance of the Moorfields Acuity Chart. *Available from Peter Allen and Associates*

Vanishing optotypes

In the seventies, researchers suggested the use of high-pass acuity targets to measure acuity;[15] these are letters in which the low spatial frequency content (where letters particularly differ) is effectively filtered out leaving the higher frequencies intact ('passed').

The letters are typically designed with a black core and white surround, the mean luminance of which is equal to the grey background on which they are presented. Since the detection and recognition thresholds are similar, these letters seem to quickly 'vanish' when the recognition threshold is reached in normal subjects. It is this characteristic behaviour that has led to their description as 'vanishing optotypes'.

However, it has been shown that in diseased foveas or under non-foveal viewing conditions, such as in patients with AMD, the detection and recognition thresholds for these optotypes can be quite different; this is because the eye still possesses sufficient cells to detect contrast in the stimulus but no longer has enough to properly resolve the target (termed 'under-sampling').

Until now, relatively little attention has been given to vanishing optotypes in the clinical field. The most familiar use of high-pass targets is in the Cardiff Acuity cards[16] developed by Dr Maggie Woodhouse at Cardiff University; this test incorporates these stimuli as pictures in a preferential looking task for infants such that a gaze shift towards the image, either at the top or bottom of the card, is taken as indicative that the image was detected, the assumption being that it is simultaneously resolved.

The Moorfields Acuity Chart

Recently, 'vanishing optotypes' have been incorporated into the new Moorfields Acuity Chart ***(see Figure 5)*** as a letter identification test developed at Moorfields Eye Hospital in collaboration with both UCL and Ulster universities. This chart follows all the design principles of the ETDRS chart, incorporating a logMAR format, but the Sloan letter set is presented in a high-pass design. These letters have been shown to be much more equally discriminable,[17,18] since the low spatial frequencies, where letters vary most, are filtered out, reducing measurement variability compared to conventional letter designs. Furthermore, acuity results have been shown to be less affected by both the scoring and termination rules employed,[19] making these charts more robust to examiner testing practices. Since the visual system must rely on the higher spatial frequencies for recognition, letter thresholds are larger than those obtained with conventional logMAR charts, as one would expect. In a study involving subjects with AMD,[20] the Moorfields Acuity Chart demonstrated a significant improvement over the ETDRS chart in detecting functional vision loss without changing the test task that patients are already so familiar and comfortable with.

Conclusion

While current, supposedly gold standard, tests for visual acuity measurement may have their limitations, it is important that the clinician establishes a strict testing protocol. Recommendations include encouraging a patient to guess when unsure to ensure a fully forced-choice procedure with consistent termination rules. Good studies examining the use of different termination rules,[19,21] have recommended the use of a 'four-out-of-five-wrong' criterion and single letter scoring to yield lowest TRV, ensuring accurate and repeatable visual acuity measurements on a logMAR chart. Computerised acuity measurement devices encourage such practice to be adhered to, particularly when non-experienced staff may administer visual acuity testing.

Perhaps now, in the 21st century, it is time to embrace new letter design charts, which retain the positive attributes of logMAR designs but display greater repeatability and better sensitivity when measuring visual performance in diseases such as AMD. This will become even more important as new therapies come on line to treat such conditions in their early stages. ●

Authors

Nilpa Shah is an optometrist at Moorfields Eye Hospital. She is completing a PhD supervised by Professor Roger Anderson and Professor Steven Dakin which has led to the development of the Moorfields Acuity Chart, a project funded by Fight for Sight and the special trustees of Moorfields Eye Hospital.

Steven Dakin is Head of the School of Optometry and Vision Science at the University of Auckland. Prior to this he held the post of Professor of Visual Psychophysics at the UCL Institute of Ophthalmology.

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Exam questions

Under the enhanced CET rules of the GOC, MCQs for this exam appear online at www.optometry.co.uk. Please complete online by midnight on 10 June 2016.
You will be unable to submit exams after this date. CET points will be uploaded to the GOC within 10 working days. You will then need to log into your CET portfolio by clicking on 'MyGOC' on the GOC website (www.optical.org) to confirm your points.

References

Visit www.optometry.co.uk, and click on the 'Related CET article' title to view the article and accompanying 'references' in full.

Course code: C-51064 Deadline: 10 June 2016

Learning objectives

- Understand the latest advances in the types of charts available for measuring visual acuity (Group 2.5.3)
- Understand the different methods for assessing visual acuity (Group 7.1.5)

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